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Abstract: The objectives of the study were to compare the ovarian activity of Holstein-Friesian (CH HF), Fleckvieh (CH FV) and Brown Swiss (CH BS) dairy cows of Swiss origin with that of Holstein-Friesian (NZ HF) dairy cows of New Zealand origin, the latter being used as a reference for reproductive performance in pasture-based seasonal calving systems. Fifty, second-lactation NZ HF cows were each paired with a second-lactation Swiss cow (17, 15 and 18 CH HF, CH FV and CH BS respectively) in 13 pasture-based, seasonal-calving commercial dairy farms in Switzerland. Ovarian activity was monitored by progesterone profiling from calving to first breeding service. CH BS cows produced less energy-corrected milk (mean 22 · 8 kg/d) than the other breeds (26 · 0-26 · 5 kg/d) during the first 100 d of lactation. CH HF cows had the lowest body condition score (BCS) at calving and the greatest BCS loss from calving to 30 d post partum. Commencement of luteal activity (CLA) was later for NZ HF than for CH FV (51 · 5 v. 29 · 2 d; P <0 · 01), with CH HF and CH BS intermediate (43 d). On average, NZ HF and CH HF cows had one oestrous cycle before the onset of the seasonal breeding period; this was less (P<0 · 01) than either CH FV (1 · 7) or CH BS (1 · 6). There was a low prevalence of luteal persistency (3%) among the studied cows. First and second oestrous cycle inter-ovulatory intervals did not differ between breeds (20 · 5-22 · 6 d). The luteal phase length of CH BS during the second cycle was shorter (10 · 6 d) than that of the other breeds (13 · 8-16 · 0 d), but the inter-luteal interval was longer (9 · 8 d v. 7 · 0-8 · 0 d). The results suggest that the Swiss breeds investigated have a shorter interval from calving to CLA than NZ HF cows.

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Ovarian activity in Fleckvieh, Brown Swiss and two strains of Holstein-Friesian cows in pasture-based, seasonal calving dairy systems

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The objectives of the study were to compare the ovarian activity of Holstein-Friesian (CH HF), Fleckvieh (CH FV) and Brown Swiss (CH BS) dairy cows of Swiss origin with that of Holstein-Friesian (NZ HF) dairy cows of New Zealand origin, the latter being used as a reference for reproductive performance in pasture-based seasonal calving systems. Fifty, second-lactation NZ HF cows were each paired with a second-lactation Swiss cow (17, 15 and 18 CH HF, CH FV and CH BS respectively) in 13 pasture-based, seasonal-calving commercial dairy farms in Switzerland. Ovarian activity was monitored by progesterone profiling from calving to first breeding service. CH BS cows produced less energy-corrected milk (mean 22·8 kg/d) than the other breeds (26·0–26·5 kg/d) during the first 100 d of lactation. CH HF cows had the lowest body condition score (BCS) at calving and the greatest BCS loss from calving to 30 d post partum. Commencement of luteal activity (CLA) was later for NZ HF than for CH FV (51·5 *v*. 29·2 d; $P<0·01$), with CH HF and CH BS intermediate (43 d). On average, NZ HF and CH HF cows had one oestrous cycle before the onset of the seasonal breeding period; this was less ($P<0·01$) than either CH FV (1·7) or CH BS (1·6). There was a low prevalence of luteal persistency (3%) among the studied cows. First and second oestrous cycle inter-ovulatory intervals did not differ between breeds (20·5–22·6 d). The luteal phase length of CH BS during the second cycle was shorter (10·6 d) than that of the other breeds (13·8–16·0 d), but the inter-luteal interval was longer (9·8 d *v*. 7·0–8·0 d). The results suggest that the Swiss breeds investigated have a shorter interval from calving to CLA than NZ HF cows.

Keywords: Genetic strain, fertility, progesterone.

Pasture-based seasonal-calving dairy production systems have been introduced into Switzerland (CH) in the past 10 years to reduce production costs (Blättler et al. 2004). These systems require that herd feed demand matches pasture growth (Holmes et al. 2007) which is achieved by having discrete periods of breeding and calving lasting 10–14 weeks on an annual cycle. At the cow level, each step of the reproductive process is crucial (ovarian activity, oestrus, insemination and the establishment of pregnancy) and the choice of an adapted breed or strain is a key of the system.

Many studies of Holstein-Friesian (HF) cows from differing geographical origins and breeding objectives report that a high proportion of North American (NA) genetic background is linked with poorer reproductive performance (Horan et al. 2005; Fulkerson et al. 2008; Macdonald et al. 2008), compromising their suitability for compact calving systems. Some of this poorer performance has been linked to ovarian dysfunction, in particular, a high proportion of persistent corpus luteum (Royal et al. 2002; Petersson et al. 2006).

Although Swiss dairy cows have been highly influenced by NA genetics, as local dual-purpose breeds were crossed

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with NA Red Holstein, Brown Swiss or HF breeds from the late 1960s (Flückiger, 1990; Wegmann et al. 1999; Hagger, 2005), functional traits have also been an important component of Swiss genetic selection programmes for more than three decades (Böbner, 1994).

A 3-year experiment (2007–2009) was thus designed to examine the suitability of the three predominant Swiss dairy breeds, Swiss Holstein-Friesian (CH HF), Swiss Fleckvieh (CH FV) and Swiss Brown Swiss (CH BS) for seasonal-calving, pasture-based Swiss milk production systems, by comparing them with New Zealand (NZ) Holstein-Friesian (NZ HF) cows; the latter being chosen as a reference population, recognized for their ability to achieve good fertility in such systems (Kolver et al. 2002; Horan et al. 2005; Macdonald et al. 2008). Reproductive performance differed among breeds (Piccand et al. 2011) with CH FV cows achieving the best reproductive performance: high submission and conception rates led to high pregnancy rates early in the breeding period. Although NZ HF cows achieved a similar pregnancy rate at the end of the breeding period, only 32% were pregnant within 3 weeks owing to a low submission rate. Overall, CH HF cows had lower reproductive performance and CH BS were intermediate. Overall, these results suggested possible differences in the underlying ovarian activity.

In the present study, we focused on the second year of this experiment to investigate to what extent these differences in reproductive performance among breeds were associated with differences in their ovarian activity. Accordingly, ovarian activity and ovulatory cycle patterns were compared between CH HF, CH FV, CH BS and NZ HF cows through progesterone profile analysis.

Materials and Methods

Experimental design

Fifty NZ HF animals were sourced as pregnant heifers from Ireland, imported into Switzerland in late 2006, and randomly allocated in January 2007 to the commercial farms involved in the project. On every farm, each NZ HF cow was paired with a Swiss breed cow, ensuring the pair was balanced for calving date and age. All trial cows were managed similarly within herd, with the farmer in charge of all management decisions concerning his herd.

The observations reported here were undertaken on 13 selected farms from January to July 2008 and involved the 100 second-lactation cows (50, 17, 15, 18 cows of NZ HF, CH HF, CH FV, CH BS, respectively, on 13, 3, 5 and 7 farms, respectively).

Animals

NZ HF. The 50 NZ HF cows were of NZ genetic origin, a strain of HF selected within seasonal calving pasture-based dairy systems for high milk-component production, fertility, and longevity. These animals had at least two generations of NZ ancestry, represented 11 NZ HF sires (86% from five sires) and had an average pedigree index Breeding Worth of NZ\$88 ± 14. They were, therefore, representative of the 2005-born HF in New Zealand (NZ\$87 ± 42; October 2009, R Wood, NZ Animal Evaluation Limited, Hamilton, New Zealand, personal communication).

CH HF. The 17 CH HF cows were from a HF strain of NA origin, but selected within a breeding index that included both milk production and functional traits. These animals represented 13 CH HF sires. Their average pedigree index for milk production (IPQ) was 103 ± 7·7. They were, therefore, representative of the 2005-born HF in Switzerland (104 ± 9·3 IPQ; November 2009, E Barras, Holstein Association of Switzerland, Posieux, Switzerland, personal communication).

CH FV. The 15 CH FV were crosses between Simmental and Red Holstein breeds, with an average of 67 ± 12% Red Holstein genetics. The herd society's breeding objectives include milk production, functional traits, and beef characteristics. These animals represented 13 CH FV sires. Their pedigree index for milk production (ILM) was 106 ± 5·4. They were, therefore, representative of the CH FV living population (101 ± 9·8 ILM; November 2009, A Bigler, Swissherdbook, Zollikofen, Switzerland, personal communication).

CH BS. The 18 CH BS were Brown Swiss cows, mainly of NA origin with only 6 ± 5% of Original Brown Swiss genetics. They were selected using a balanced breeding index, including milk production and functional traits. These animals represented 15 CH BS sires. Their average pedigree index for milk production (MIW) was 104 ± 5·4. They were, therefore, representative of the 2005-born Brown Swiss in Switzerland (104 ± 7·9 MIW; November 2009, B Bapst, Swiss Brown Cattle Breeders' Federation, Zug, Switzerland, personal communication).

Farms and herd management

Farms. The 13 dairy farms were located in different geographical regions and altitudes: eight were located on the Swiss Plateau (lowland), four in the Pre-Alps (hill country) and two in the Jura (hill and mountain country), with an altitude ranging from 440 to 1050 m and a pasture growth period ranging from 230 to 170 d (Jeanneret & Vautier, 1977). Management objectives were similar between herds (low-input, pasture-based, spring-calving system).

Feeding. As generally observed in Switzerland, the winter lactating cow ration (from calving to turn out, at 36 ± 27 days in milk) always contained a grass sourced forage. It consisted of hay, or hay and grass silage, or grass silage and maize silage ($n=6$, 6 and 1 farm, respectively). Concentrate was fed daily at a rate of $3{\cdot}5\pm1{\cdot}8$ kg DM/cow to lactating cows during the winter period (mean 303 ± 131 kg/cow per lactation). Winter rations were estimated to contain $6{\cdot}2\pm0{\cdot}4$ MJ NE_L/kg DM and $15\pm2{\cdot}1$% CP/kg DM (one sample/forage type per farm). Cows were managed on pasture from 23 March 2008 (±14 d) and progressively reached full grazing after a 2–3 weeks transition period. At grazing, supplementary feed was offered only during periods of pasture deficit. From the time of turning out to pasture until the end of June, pasture was estimated to contain $6{\cdot}2\pm0{\cdot}4$ MJ NE_L/kg DM and $21\pm3{\cdot}3$% CP/kg DM (one sample of offered pasture/month per farm). The dry period ration consisted of hay or grass silage of lower quality than the lactating cow ration.

Reproductive events. The average day of the planned start of mating (PSM) was 16 April 2008 (±15 d). Three farms did not follow strict seasonal rules so did not have fixed PSM dates. For the cows on these farms, artificial PSM dates were calculated for each cow by adding a voluntary waiting period (VWP) to the calving date. The VWP was defined for each farm as the shortest observed interval from calving to service (33, 35 and 37 d). All calving dates, artificial insemination (AI) dates, health events and treatments were recorded. For cows not showing oestrus before PSM, the need for treatment was assessed individually by the farm veterinarian. From the 13 farms, seven introduced a bull into the herd 45 ± 15 d after PSM (i.e. after two AI cycles).

Animal measurements and variable definitions

Milk yield, body condition score and live-weight. Milk volume and composition were assessed monthly. Samples were analysed for fat, protein and lactose with an infrared analyser (Foss, Hillerød, Denmark). From these monthly records, 100-d cumulative variables were calculated as follows:

$$\sum_{i=0}^{n}\frac{\mathrm{value}_i+\mathrm{value}_{i+1}}{2}\times(\mathrm{days}_{i+1}-\mathrm{days}_i)$$

where value_i and days_i are the value (e.g. milk yield) and days after calving of the i^{th} sample, respectively, n is the number of samples <100 days after calving, value_0 is set to value_1, days_0 is set to 0, and days_{n+1} is set to 100. Body condition score (BCS) was assessed monthly on a 1–5 scale in increments of 0·25 (Edmonson et al. 1989) by the same trained operator on all farms. Calving BCS was considered as the maximum of the two one-month-spaced scores that framed calving. Body condition scores at 30 and 100 d post partum were calculated from individually fitted cubic spline smoothing curves (smooth.spline function: smoothing parameter = 0·25, BCS weights = 5, 2 and 1 at calving, before and after 60 d post partum, respectively; R Development Core Team, 2009). Cows were weighed on days 38 ± 19, 116 ± 25 and 281 ± 28 post partum, using a mobile weigh platform (Tru-Test, Auckland, New Zealand). Lactation live-weight was averaged over these three values to calculate milk production efficiency (milk yield per metabolic live-weight, i.e. $Lwt^{0{\cdot}75}$).

Milk progesterone analysis. Milk samples were collected after cluster removal at the morning milking every second day between calving and first mating date. Additional samples were collected at 10, 21 and 28 d after the first insemination. Samples were quickly frozen and stored for 12 months at −18 °C until analysis. Milk sample were defrosted overnight at 5 °C and then centrifuged for 10 min at 3000 rpm at 4 °C just before analysis. Milk progesterone (P_4) concentration was assayed in skim milk samples by ELISA (Nalge Nunc International, New York, USA) as described by Meyer et al. (1986). Range of detectable concentration was 0·2–12·5 ng/ml. Intra- and inter-assay coefficients of variation were 23% and 23%, 12% and 26%, and 15% and 17% for skim milk control samples with low, medium and high progesterone concentrations (1·4, 2·3 and 3·0 ng/ml), respectively.

Progesterone profile analysis. Use of P_4 to indicate the onset of luteal activity was similar to the method reported by Royal et al. (2000). Cows were defined as being in luteal phase following ovulation if at least two consecutive samples had milk P_4 concentrations greater than 0·8 ng/ml ('positive' sample; Weiss et al, 2004). Commencement of luteal activity (CLA) was the calculated interval from calving to the first positive sample of the first luteal phase, minus 1 d (sampling bias correction). Inter-ovulatory interval (IOI) was the interval between the first positive samples of two consecutive luteal phases. Luteal phase length (LPL) was the interval from the first to the last positive sample of a luteal phase plus 2 d. Inter-luteal interval (ILI) was the interval between the last and the first positive samples of two consecutive luteal phases minus 2 d. A transient progesterone rise (TPR) corresponds to a single positive sample; TPRs were recorded as they may, in some cases, have been part of a short luteal phase, which was not detected by the sampling routine. Progesterone profiles were classified as Normal, Persistent Corpus Luteum (PCL, if at least one LPL was ⩾19 d), Delayed Ovulation of type I (DOV-I, if CLA ⩾45 d) or Delayed Ovulation of type II (DOV-II, at least one ILI was ⩾12 d). The number of cycles by PSM corresponded to the number of luteal phases started by PSM.

Traditional reproductive parameters. Conception to first service (FSC) was confirmed by three positive P_4 samples after AI (days 10, 21 and 28 post AI) and a corresponding subsequent calving date. In two cases conception was only confirmed by positive P_4 samples (one cow was culled before calving and one had a mummified calf). Sampling stopped after first service, so for inseminations without P_4 information ($n=46$ cows), dates of conception were

Table 1. Postpartum ovarian activity parameters of New Zealand Holstein-Friesian (NZ HF; $n=50$), Swiss Holstein-Friesian (CH HF; $n=17$), Swiss Fleckvieh (CH FV; $n=15$) and Swiss Brown Swiss (CH BS; $n=18$) second-lactation dairy cows managed in seasonal-calving pasture-based dairy systems of Switzerland (n are given per breed in brackets). SED_{max} is given for continuous variables only (binomial variables were analysed on logit-scale)

	n	NZ HF	CH HF	CH FV	CH BS	SED_{max}	P_{breed}
Profile characteristics							
Calving to CLA† interval, d	100	51·5 ^{b}‡ (50)	43·0 ^{ab} (17)	29·2 ^{a} (15)	42·7 ^{ab} (18)	9·47	0·01
CLA to AI interval, d	73	33·3 (33)	30·9 (12)	36·7 (13)	39·2 (15)	8·19	0·69
Cycles before planned start of mating (n)	97	0·99 ^{a} (49)	0·98 ^{ab} (16)	1·71 ^{c} (14)	1·57 ^{bc} (18)	0·364	< 0·01
Proportion of anoestrous cows by							
day 45 post partum,%	100	48·5 (50)	22·0 (17)	9·0 (15)	34·4 (18)	—	0·10
day 70 post partum,%	100	7·7 (50)	11·1 (17)	8·2 (15)	4·6 (18)	—	0·93
Transient progesterone rises,%	100	32·0 (50)	29·4 (17)	13·3 (15)	38·9 (18)	—	0·52
1st cycle							
Inter-ovulatory interval, d	58	17·0 (26)	16·8 (8)	18·5 (13)	17·5 (11)	3·33	0·93
Luteal phase length, d	82	9·6 (38)	10·5 (16)	10·9 (15)	8·9 (13)	1·74	0·60
Inter-luteal interval, d	58	7·4 (26)	6·1 (8)	7·3 (13)	8·9 (11)	2·40	0·66
Inter-ovulatory interval $\leqslant$ 15 d,%	58	46·2 (26)	50·0 (8)	30·8 (13)	27·3 (11)	—	0·58
1st and 2nd cycles with IOI§ of 16–30 d							
Inter-ovulatory interval, d	63	20·5 (24)	22·6 (7)	21·9 (18)	20·8 (14)	1·63	0·33
Luteal phase length, d	63	13·8 ^{b} (24)	16·0 ^{b} (7)	13·8 ^{b} (18)	10·6 ^{a} (14)	1·60	< 0·01
Inter-luteal interval, d	63	7·0 ^{b} (24)	7·1 ^{b} (7)	8·0 ^{b} (18)	9·8 ^{a} (14)	1·15	< 0·01

† Commencement of luteal activity
‡ $^{a, b, c}$ values without a common superscript letter are significantly different ($P<0·05$)
§ Inter-ovulatory interval

estimated from the mating dates and the subsequent calving date, with consideration of the sire's breed gestation length. When several inseminations were performed within the interval [expected − 10; expected + 14], the last AI event was chosen. For natural mating without a recorded mating date, the date of conception was estimated by subtracting the gestation length for the sire's breed from the subsequent calving date.

Statistical analyses

The GenStat procedure CENSOR (VSN International Ltd., 2007) was used to obtain an estimate of the interval from calving to first luteal activity for cows with censored data (i.e. for cows that had a minimum value for the interval when the P4 monitoring stopped but no actual data). Breed was included as a fixed effect, farm and pair within farm were included as random effects. Cows treated for anoestrus were removed from progesterone analysis from the day of the treatment.

Continuous variables were analysed by linear mixed models including breed as a fixed effect and farm and pair within farm as random effects. Binomial variables were analysed by mixed logistic regressions including breed as a fixed effect and farm as a random effect. Results are expressed as predicted probabilities for each breed. These analyses were performed using R statistical software (lmer and glmer functions, respectively; Bates & Maechler, 2010; R Development Core Team, 2009).

Results

Progesterone-related parameters and reproductive performance

The timing of CLA differed between breeds (Table 1): CH FV cows had an earlier CLA than NZ HF cows, with CH HF and CH BS cows intermediate. This earlier resumption in CH FV cows was explained by a very compact resumption in comparison with NZ HF cows, as shown in Fig. 1. Profiles were classified as PCL and DOV-II from only 3 and 6 cows, respectively, whereas 42 cows had CLA $\geqslant$ 45 d (DOV-I). There was a tendency for more NZ HF cows to be anoestrous at 45 d post partum (DOV-I) than CH HF ($P<0·1$) and CH FV ($P<0·06$) cows. As a result, NZ HF cows completed fewer oestrous cycles before PSM than CH FV cows (Table 1).

First cycle characteristics did not differ between breeds. When first and second cycles were pooled and IOI ranging from 16 to 30 d were considered (i.e. excluding short first cycles and extreme values), CH BS had both shorter LPL and longer ILI than other breeds (Table 1). Traditional reproduction parameters are given in Table 2, rather as illustrative key figures than as statistically compared figures, owing to the low number of animals.

Milk yield and BCS

CH BS cows produced less energy-corrected milk (ECM) and milk fat and protein than other breeds during early lactation (Table 3). When accounting for $Lwt^{0·75}$, a dairy efficiency gradient from the least to the most efficient was observed

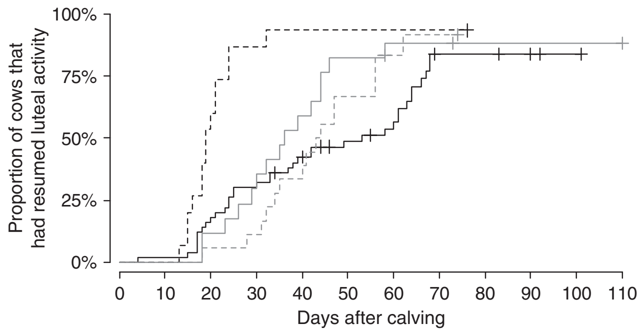

Fig. 1. Proportions of New Zealand Holstein-Friesian (NZ HF; $n=50$; solid black line), Swiss Holstein-Friesian (CH HF; $n=17$; dashed grey line), Swiss Fleckvieh (CH FV; $n=15$; dashed black line) and Swiss Brown Swiss (CH BS; $n=18$; solid grey line) second-lactation dairy cows managed in seasonal-calving pasture-based dairy systems of Switzerland having their luteal activity resumed. This illustrative plot was drawn from Kaplan-Meier estimates of survival curves that do not account for the farm effect (the calving to commencement of luteal activity intervals and the proportions of anoestrous cows adjusted for farm effect are given in Table 1)

from CH BS to CH FV, CH HF and NZ HF. CH FV cows had highest BCS at calving and through early lactation (Table 3). Conversely, CH HF had the lowest calving BCS and the greatest BCS loss post partum, with loss most pronounced in the first 30 d (Table 3).

Discussion

Commencement of luteal activity

The NZ HF strain took longer to resume ovarian activity after calving than the other breeds. This result is consistent with a previous report that extended anovulatory periods are a major source of reproductive failure in NZ dairy cows (Macmillan, 2002). To our knowledge, NZ HF always have either longer (McNaughton et al. 2003, Macdonald et al. 2008) or similar (Horan et al. 2005, Chagas et al. 2006), but never shorter CLA than NA HF, despite their higher fertility.

The longer interval from calving to CLA in the NZ HF is in agreement with the high positive correlation between CLA and Predicted Transmitting Abilities for fat (Veerkamp et al. 2000; Royal et al. 2002). The NZ HF strain has been selected for high milk solids (fat plus protein) yield for many decades. In comparison, the three Swiss breeds have been mostly selected on milk volume, which has a lower genetic correlation with CLA. Interestingly, the average CLA increased linearly with the production trait weightings in the selection indices of the four breeds: 39%, 54%, 53% and 67% for CH FV, CH BS, CH HF and NZ HF, respectively (year 2009; Swiss herdbook, Swiss Brown Cattle Breeders' Federation, Holstein Association of Switzerland, New Zealand Animal Evaluation Unit).

According to a recent review (Cutullic, 2010), an average interval from calving to CLA of 30 d would be expected for herds of multiparous cows with such milk yields. The reason for the longer interval in the present study is not known. It may be related to nutrition or BCS. Although recent studies reported no effect of post-partum feeding level effect on CLA (Horan et al. 2005; Burke & Roche, 2007; Cutullic et al. 2011), possible differences in pre-partum feeding level, calving BCS (Burke & Roche, 2007), or differences in the proportion of structural to non-structural carbohydrates in post-partum diets (Gong et al. 2002; Burke et al. 2010) between the farms on this study and that reported by Cutullic (2010) cannot be excluded.

Both BCS at calving and BCS change in early lactation, indicating the energy balance of the cow, influence timing of CLA (Butler et al. 1981; Roche et al. 2009; Friggens et al. 2010). Although these associations are plausible within breed, they are unlikely to account for the breed differences reported here. For example, based on their BCS profile, NZ HF should resume ovarian activity earlier. Consistent with this, Pollot et al. (2008) could explain differences in timing to CLA by energy deficit differences within strain, but not between strains. This suggests that there are inherent breed influences on the timing of CLA beyond that of BCS, BCS change or energy balance.

Oestrous cycle traits

Oestrous cycle characteristics of CH BS differed from the other breeds, with a shorter LP and longer ILI, although IOI was similar. This may be associated with a slower increase in P_4 at the start of the luteal phase for CH BS cows, similar to that previously reported by Yenikoyé et al. (1981) and Meier et al. (2009). Differences in the follicular wave patterns, not measured in the present study, may also underlie the observed cycle differences. The similarity of IOI however suggests that the numbers of follicular waves per cycle were similar across the breeds (Bleach et al. 2004).

Ovarian abnormalities were scarce, apart from delayed resumption of luteal activity post partum. The late resumption of luteal activity in the present study may, in part, have prevented the occurrence of prolonged luteal phases; however it may also be a consequence of different genetic selection priorities within the breeds evaluated. In Sweden, for example, where fertility traits were included in the genetic index in the 1970s, Petersson et al. (2006) reported only 6 and 11% prolonged luteal phase profiles in Red and White and Holstein breeds respectively.

Overall reproductive performance

The low number of animals in this study limits the conclusions that can be drawn about overall reproductive performance. However, the numerical trends observed have been confirmed by the 3-year analysis reported by Piccand et al. (2011).

Late resumption of luteal activity probably explained the low 21-d submission rate in the NZ HF. However, because normal ovarian activity with fertile ovulations resumed

Table 2. Reproduction parameters of New Zealand Holstein-Friesian (NZ HF; $n=50$), Swiss Holstein-Friesian (CH HF; $n=17$), Swiss Fleckvieh (CH FV; $n=15$) and Swiss Brown Swiss (CH BS; $n=18$) second-lactation dairy cows managed in seasonal-calving pasture-based dairy systems of Switzerland (n are given per breed in brackets). SED_{max} is given for continuous variables only (binomial variables were analysed on logit-scale)

	n	NZ HF	CH HF	CH FV	CH BS	SED_{max}	P_{breed}
Calving to PSM †, d	100	54 (50)	55 (17)	52 (15)	56 (18)	3·29	0·71
21-d submission rate,%	100	59 (50)	56 (17)	80 (15)	78 (18)	—	0·38
Conception to first service,%	98	60 (50)	46 (15)	44 (15)	45 (18)	—	0·56
Conception to first and second service,%	98	70 (50)	59 (15)	72 (15)	62 (18)	—	0·84
Pregnant within 3 weeks of PSM,%	97	35 (49)	27 (15)	47 (15)	39 (18)	—	0·76
Pregnant within 6 weeks of PSM,%	97	71 (49)	61 (15)	56 (15)	68 (18)	—	0·80
Pregnant within 9 weeks of PSM,%	97	81 (49)	64 (15)	77 (15)	80 (18)	—	0·68
Pregnant within 12 weeks of PSM,%	97	88 (49)	77 (15)	80 (15)	87 (18)	—	0·72
Cows treated for anoestrus,%	100	11 (50)	13 (17)	12 (15)	0 (18)	—	0·18

† Planned start of mating

Table 3. Milk production and body condition of New Zealand Holstein-Friesian (NZ HF; n=50), Swiss Holstein-Friesian (CH HF; $n=17$), Swiss Fleckvieh (CH FV; $n=15$) and Swiss Brown Swiss (CH BS; $n=18$) second-lactation dairy cows managed in seasonal-calving pasture-based dairy systems of Switzerland

Item	NZ HF	CH HF	CH FV	CH BS	SED_{max}	P_{breed}
Milk production over first 100 d						
milk yield, kg/d	25·2 ^{ab}†	26·8 ^{b}	26·0 ^{ab}	23·7 ^{a}	1·20	0·08
ECM‡ yield, kg/d	26·3 ^{b}	26·5 ^{b}	26·0 ^{b}	22·8 ^{a}	1·31	< 0·01
milk fat, kg/d	1·08 ^{b}	1·07 ^{b}	1·05 ^{b}	0·89 ^{a}	0·064	< 0·01
milk protein, kg/d	0·86 ^{b}	0·86 ^{b}	0·84 ^{b}	0·75 ^{a}	0·040	< 0·01
ECM efficiency § ($\text{kg.day}^{-1}.\ \text{kg}^{-0·75}$)	0·243 ^{c}	0·225 ^{b}	0·215 ^{ab}	0·197 ^{a}	0·012	< 0·01
Body condition score (BCS), (1–5) scale						
BCS at calving	3·16 ^{b}	2·95 ^{a}	3·41 ^{c}	3·27 ^{bc}	0·134	< 0·01
BCS at 30 d	2·92 ^{b}	2·58 ^{a}	3·25 ^{c}	3·09 ^{c}	0·121	< 0·01
BCS at 100 d	2·78 ^{b}	2·35 ^{a}	3·13 ^{c}	2·86 ^{b}	0·123	< 0·01
BCS change from calving to 30 d	−0·26 ^{b}	−0·42 ^{a}	−0·16 ^{b}	−0·16 ^{b}	0·090	0·02
BCS change from calving to 100 d	−0·38 ^{b}	−0·60 ^{a}	−0·28 ^{bc}	−0·40 ^{ab}	0·128	0·07

† $^{a,\,b,\,c}$ values without a common superscript letter are significantly different ($P<0·05$)
‡ Energy corrected milk (4·0% fat, 3·2% protein and 4·8% lactose)
§ Energy corrected milk per average lactation metabolic weight, i.e. per (average lactation BW)$^{0·75}$. Seventeen cows with missing weight were excluded from the analysis

quickly beyond CLA, they achieved normal 6-week and 12-week pregnancy rates. According to McNaughton et al. (2007), only resumption of luteal activity after 70 d post partum affects the interval from PSM to conception. This is in agreement with the high final pregancy rates observed in CH BS and NZ HF cows, although respectively one-third and one-half of these cows were 'delayed' classified (CLA ⩾ 45 d); indeed, most of the cows had resumed luteal activity by day 70 post partum (94 and 90% respectively). In CH HF cows, numerically lower pregnancy rates achieved through the breeding season seemed mostly due to poor fertility to insemination or to low oestrus expression, rather than to abnormal ovarian activity, in agreement with many experiments comparing NZ HF strains with high productivity NA strains (Verkerk et al. 2000; Horan et al. 2005; Macdonald et al. 2008). In CH FV cows, the early homogenous CLA allowed a high submission rate and a high 3-week pregnancy rate, which is a non negligible advantage on the long term in compact calving systems. In the 3-year study (Piccand et al. 2011), this group achieved the best overall reproductive performance.

Conclusions

The Swiss breeds investigated have a shorter interval from calving to CLA than NZ HF cows. However, ovarian activity is only the first step of the reproductive process and the final reproductive performance is also highly modulated by later steps, such as fertility to insemination.

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